Background: What is a Boolean?

Unless you are a fairly experienced computer graphic modeler, the word “Boolean” may not generate much interest or excitement, but the introduction of boolean tools into ModelPro 3.0 greatly enhances the power of one of the most powerful Macintosh 3-D modelers.

The word Boolean comes from the surname of George Boole, a 19th century British mathematician who, in 1847, proposed a two-value system of algebraic logic. Since all computer circuits and most electrical circuits are based on a two-value system (on and off), the study of Boolean algebra has really taken off in the past fifty years. In computer graphic modeling, a Boolean has come to mean a volume that has been added, subtracted or intersected with one or more other volumes to produce a wholly unique volume. The building block volumes are usually simple primitive objects, such as cubes and spheres, which when combined with boolean operations- difference, intersection and union- can form very complex objects very quickly. For example, a car is simply the union of two or three ovoid boxes with two cylinders subtracted to form the wheel openings.

Booleans in ModelPro

ModelPro provides you with two types of boolean tools, and it’s important to understand the differences and similarities between them before you begin a modeling strategy.

The first and most important thing to keep in mind is that when ModelPro creates a boolean, it makes a polygonal mesh- that is, it creates an object made up of discrete polygonal facets which are no longer editable in ModelPro. The boolean object may be scaled, rotated and subjected to further boolean operations, but you will not be able to select individual vertices for editing since it no longer exists as a spline object. This is not a drawback by any means, but it does mean that as a general rule you should perform your boolean operations in the last phase of model creation, after all your building-block objects have been properly proportioned and positioned, since it will be difficult to reshape the object after a boolean operation. Also, pay close attention to the “Mesh Density” box that appears when the boolean tools are selected.

Tip: To access the original splines that make up a boolean, double-click on the boolean filing cabinet icon in the “Group” list. In the resulting dialog box, uncheck the “Assembly” box and close the window. Now the filing cabinet icon has changed to a normal folder. Open the folder and drag out the original spline meshes.

Tip: For very angular boolean objects, or ones that will not be very close to the camera in the rendered scene, use a low mesh density value. For very organic booleans that will appear very close to the camera, use a higher mesh density value.

The value in this box determines the “finess” of the resulting boolean, with a higher number giving a smoother surface (more facets) and a consequential rise in file size and rendering time. Keep in mind that this surface finess once set for a boolean is unaffected by the finess setting in PresenterPro rendering– once the polygon mesh has been created, it is independent of spline interpretation.

The good news is that ModelPro never deletes the spline objects that you used to create the boolean. All the objects that you used to form the boolean are contained within the boolean that appears in the “Group” list as a filing cabinet icon. If, after rendering, you decide that the boolean has to be smoother, simply re-select the spine objects and create a new boolean with a higher mesh density.

The differences between the two boolean tools provided by ModelPro is somewhat subtle but very important.

The Punch Tool

Note: In many respects, the Punch tool is a minor sub-set of the Boolean tool, and for this reason the following tutorial will focus on mastering the Boolean tool. Once boolean modeling methods are learned, the Punch tool will become self-evident.

The Punch tool, located on the bottom left of the toolbar, does exactly what it says it does- punch holes through other shapes. The three requirements for it to work are that the shape used to punch the hole is planar (flat), closed, and that the object to be punched is a spline mesh or boolean. To punch a primitive, you must first convert it to a spline mesh using the “Information” window. You can punch a spline mesh with many shapes at once, but you cannot punch more than one spline mesh at the same time. The effect of a punch operation is like taking a laser in the form of the punching shape and projecting it perpendicularly though the target spline mesh- the hole goes completely through the object, without creating caps or walls for the resulting hole(s). This is important to note, since it would be very difficult to make a perfectly-fitting cap or wall after making the punched boolean- the snapping tools will not work on the boolean form. It is also important to note that the Punch tool can operate on any spline mesh, while the Boolean tool can only operate on closed (no open sides) spline meshes. Therefore, if you wanted to cut an object that was a 180° lathe (common for symmetrical models), you would have to use the Punch tool and consequentially have to fabricate an end-cap or wall by hand.

The Boolean Tool

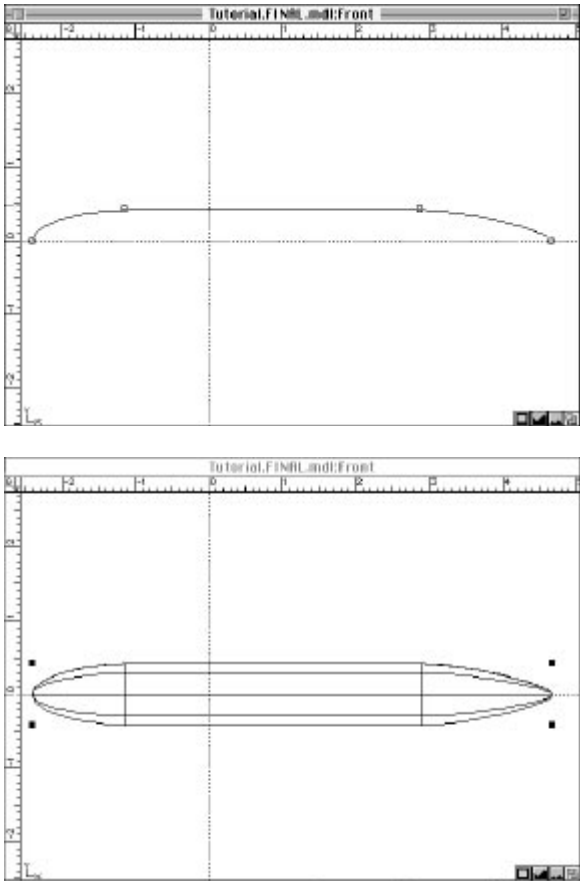
The Boolean tool is the centerpiece of ModelPro 3.0. With this one tool you will be able to quickly and easily generate very complex models from primitives and spline meshes. The key to using the tool effectively is to try and think of your model as a collection of positive and negative volumes and then determine the sequence of subtraction, intersection and union needed to form the shape of the model.

The Boolean tool is located on the bottom right of the toolbar and can be selected before or after you have selected your spline mesh for operation. Once selected, you will notice that the first spline mesh turns into a red box, denoting that this will be the mesh that the boolean will be performed on. You will also notice that there are three radio buttons in the boolean dialog box at the top of the screen– difference, intersection and union. The easiest way to picture the outcome of using these buttons is to think of two overlapping circles. Difference will create a circle with curved bite out of it where the other circle overlapped. Intersection will create a two-pointed leaf shape where the circles overlapped– the overlap itself. Union will create a shape like a solid figure 8 on its side, the merging of both circles. Obviously, it gets a little more complicated in 3-D and you may be surprised by some of the results.

Hint: For subtractive booleans, first determine whether the resultant shape should have caps and walls. If it does, you will have to use the "Boolean" tool and the building-block spline meshes will all have to be closed shapes. If caps or walls are not needed, or if the spline mesh is open, use the Punch tool.

As stated earlier, the main restriction of the Boolean tool is that all the shapes involved must be closed volumes. Primitives do not have to be converted to spline meshes as with the Punch tool, and consequentially are the most convenient building-blocks for your boolean shapes.

In this tutorial you will build a simple commercial airliner, complete with windows. This tutorial assumes you have already covered the basic ModelPro construction techniques of lathe, extrude, and duplicate.



The Fuselage

Modeling the Sections of the Airplane

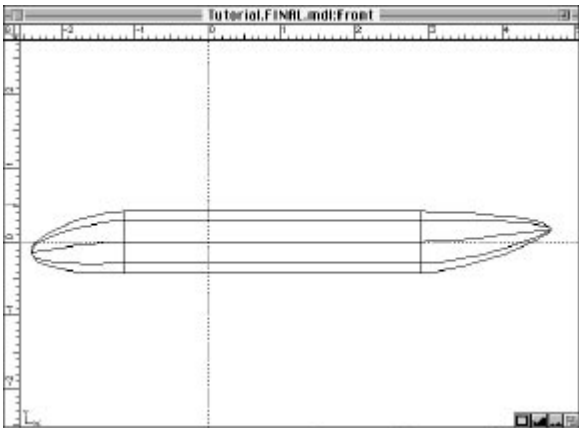
The first step in any modeling project is to create the component pieces that will be used in the boolean operations. You will start by designing the fuselage. Then you will proceed to add the wings and the stabilizer. Next you will create the cockpit. The final step will be to weld all the components together.

Designing the Fuselage

To begin, we'll draw the plane fuselage profile. In the Front window, draw a simple four-vertice profile with the Spline tool, approximating the shape of a plane fuselage. Make sure that the beginning and ending vertices have a Y-value of 0 and that the whole profile has a Z-value of 0– that is, the spline lies exactly on the X-axis. To check your vertices, double-click on them to bring up the "Move" dialog.

Select the spline profile and choose the Lathe tool. Make sure the center of the lathe is set to 0,0,0 and 360° rotation, and bank angle to 90°. The axis of rotation should be set parallel to the X-axis. Hit the "Lathe" button to create the plane fuselage.

Since modern jetliners don't really have cigar-shaped fuselages, we want to reshape the lathe to give a more realistic appearance.

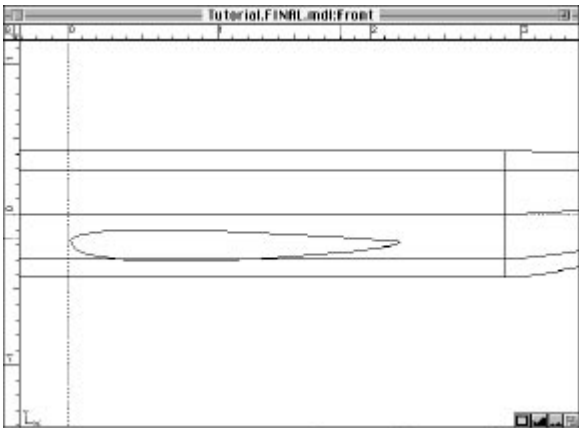


Fuselage with the nose turned down and the tail turned up.

To reshape the lathe mesh, choose the Selection tool and select the spline mesh. Then do a marquee selection(hold the shift key) of all the vertices in the "nose" of the lathe and pull them downward slightly (in the front window).Then repeat the procedure with the tail vertices, but drag them upward so that you end up with a shape like. If you are unsure about reshaping and selection methods, refer to the appropriate section in this manual.

Designing the Wings

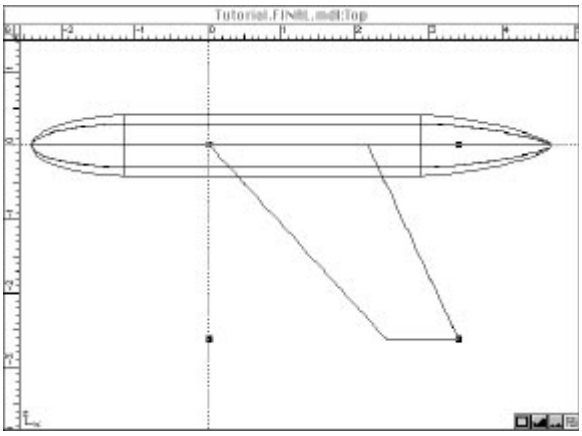
Now it's time for the wings. In the front window, use the Spline tool to create a simple airfoil shape, using no more than two or three vertices. The airfoil should be roughly sized and positioned where the root of the wing would be on the fuselage.



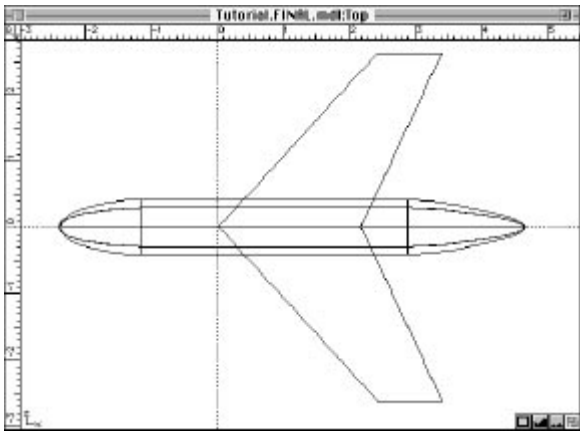
Wing spline shape in position on the fuselage.

Select the airfoil shape and choose the Extrude tool. Using the three windows, create an extrusion that extends out and rearward, as well as slightly up (+Y, to make it a dihedral wing) as it scales to about 50% of its original size. The Extrude tool is very intuitive and offers excellent feedback, but if you have problems here, refer to the extrude tutorial. You should end up with a shape like that in Figure 5.

The only remaining step to complete the airframe is to Clone the wing and mirror it about the X-axis. You can either use the Mirror tool or scale the wing by -1 in the Z-axis about the Galactic Core (model universe: 0,0,0). The nearly finished model should look as shown.



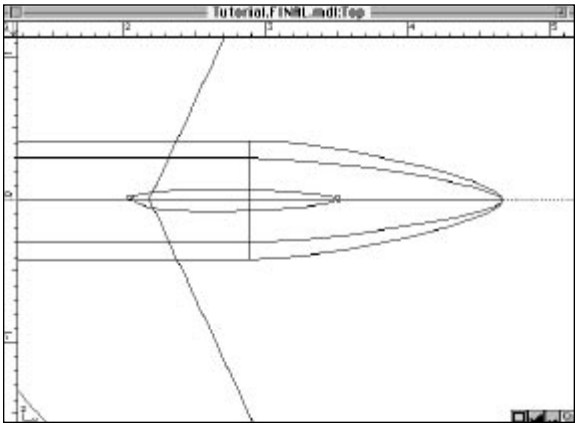
Extruded wing spline



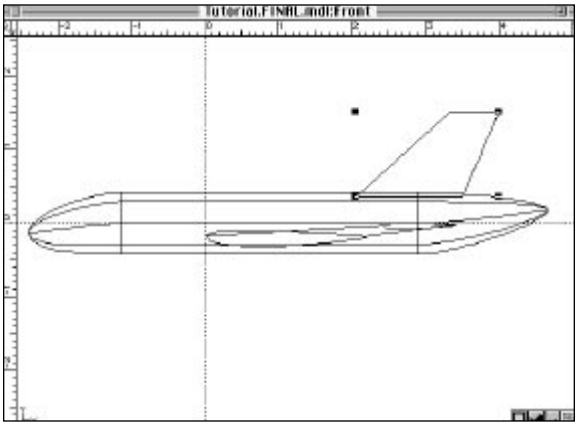
Fuselage with wings

Designing the Vertical Stabilizer

In the Top window, draw a simple two-point profile approximating the elliptical cross-section of the vertical stabilizer. Select and extrude it as you did the wing profile, upward and back as it is scaled, to form the vertical stabilizer.



Vertical stabilizer spline shape

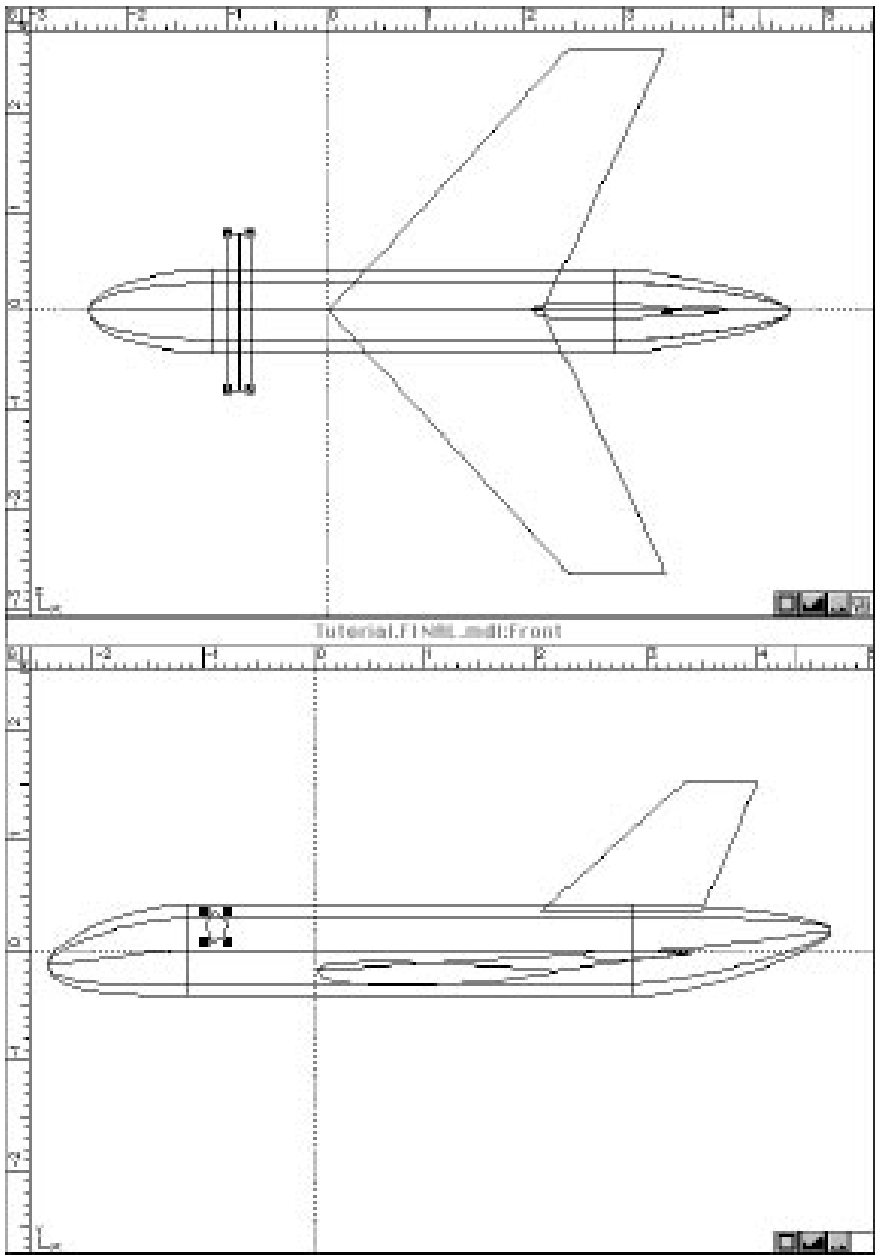


Extruded vertical stabilizer

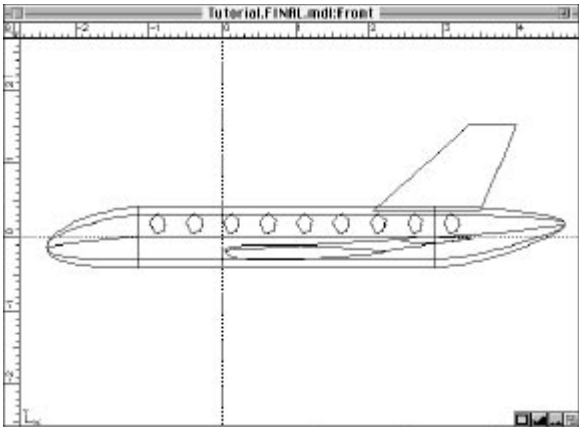
Creating the Windows

Since we are building a passenger airliner and not cargo ship, we have to put windows into our plane. To do this, choose the Primitive Cylinder tool and draw an oval about the size of a window just below the fuselage in the Front window. After creating the cylinder, check the Top window and make sure the cylinder in long enough to completely extend beyond the outline of the fuselage. It should extend at least one quarter of the length of the cylinder beyond each side of the fuselage, and to keep everything tidy, use the “Move” menu item to make sure that the cylinder is exactly centered on the Z-axis. If you’re unsure about the “Move to…” command, refer to the Tools section of this manual.

Tip: After you create the cylinder, double-click on it and make sure that in the resulting dialogue that “Top” and “Bottom” boxes in the “Caps” section are checked. If you use un-capped cylinders (that is, tubes) in this exercise, your windows will not have surfaces. Very upsetting to the passengers.



The window cylinder

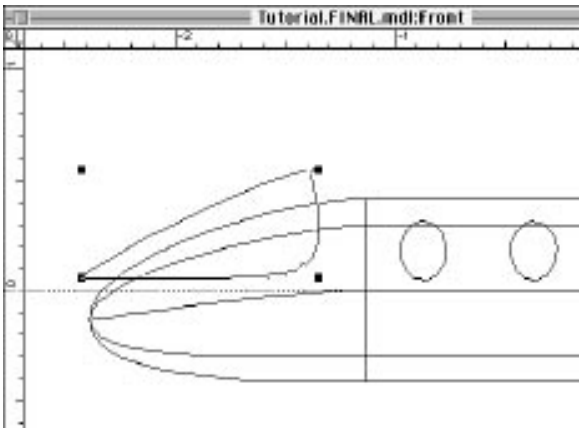


Side view with window cylinders in place

Select the cylinder and using the “Duplicate…” command from the “Edit” menu, perform a linear duplicate for 9 windows, spaced appropriately for an airliner window set. If you’re not familiar with the “Duplicate…” command, refer to “Edit” section in this manual. Notice that ModelPro was nice enough to put all the duplicated cylinders into a folder for you. When you are done, your model should look shown.

Designing the Cockpit

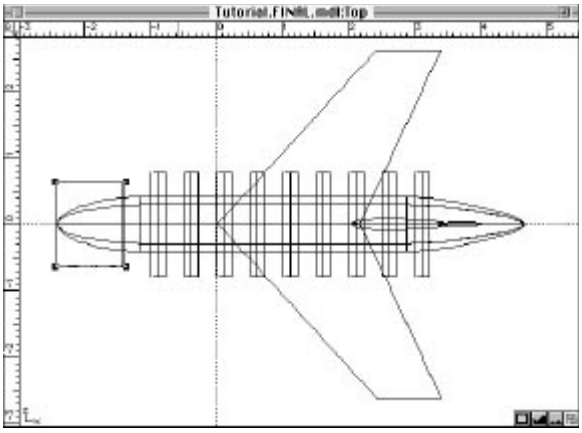
If the passengers were the folks with windows on our plane, they could expect a very, shall we say, brief flight. So the next step is create the boolean shape for the cockpit window.



Cockpit profile

Select the Spline tool and in the Front window draw a simple three- or four-point shape to form the profile of the cockpit. Note that the side of the profile that doesn’t overlap the fuselage doesn’t matter, since the boolean operation that we will perform (intersection) only evaluates the overlap between our cockpit shape and the fuselage shape- what does not intersect will be removed..

Once you've drawn your cockpit profile, you have to extrude it to form a volume that the Boolean tool can use. Select the profile and choose the Extrude tool, extruding the profile deep enough to exceed the width of the fuselage nose. Note that the settings for the Extrude tool will still have all the values for the wings extrusions- reset them so they give a straight, non-scaling extrusion by typing 0 and 1 values directly in the Extrude toolbar. Finally, use the "Move to…" menu to center the extrusion on the Z-axis.

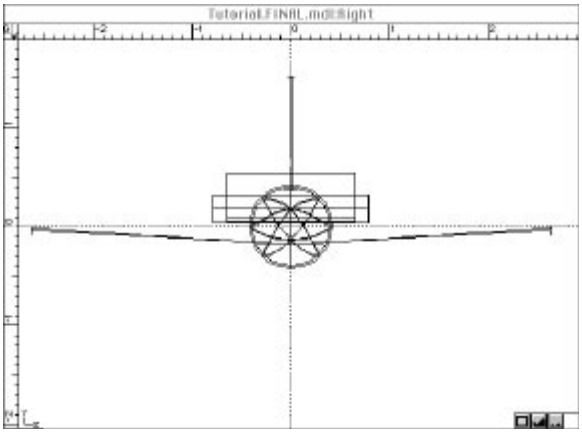


Cockpit and windows in place

Designing the Inner Wall of the Fuselage

The last piece to make before we begin the booleans is the inner wall of the fuselage. Planes, like most real-world objects, have a wall thickness instead of the mathematically pleasing zero-thickness membranes of 3-D computer models.

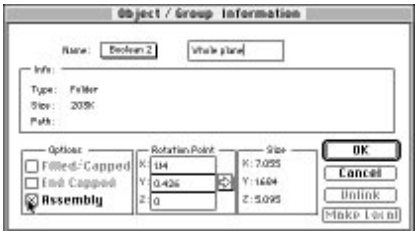
The way to make the inner shell of the fuselage is to select the fuselage and select "Clone" from the Edit menu, creating an exact duplicate of the main fuselage. Then select "Transform" from the Operations menu to scale the cloned fuselage uniformly by .95 about the center of the object. If you're having problems with this step, refer to the section in this manual on Operations. You should now have a smaller version of the fuselage nested cozily inside the main fuselage.



Front view showing, wings, vertical stabilizer, window cylinders, cockpit, and nested fuselage walls.

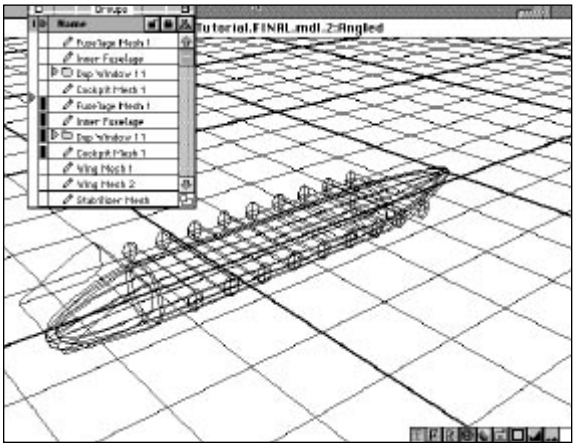
The last step before using the Boolean tool is to select the main fuselage, the inner fuselage, the cockpit extrusion, and the window cylinders folder and clone them.

This is crucial to your modeling strategy- ModelPro does not destroy the original spline meshes that you use in your booleans. Rather, it locks them up in a special folder called a cabinet (complete with a filing cabinet icons in the group list). This cabinet can be unlocked and turned into a folder to retrieve the spline meshes by double-clicking on the cabinet icon and unchecking the “Assembly” box. However, this can cause problems if you later want to perform another boolean on the boolean you’ve unlocked and removed the original spline meshes from, since ModelPro uses those spline meshes to calculate the new boolean. It’s more efficient to simply clone all the original meshes before starting your booleans so you don’t waste time unlocking the boolean and retrieving the splines to do other booleans. Note that if you reshape one of the original splines still in the boolean folder, the boolean is not automatically updated– you have make a new boolean to reflect the new shape.



Object/Group Info dialog

In the case of your plane, you need two complete sets of fuselages and windows because you’re going to make two completely different booleans using the exact same meshes- the window glass boolean and the thick-walled fuselage boolean with holes punched out to receive the window glass. To start your booleans, turn off one set of the fuselage/windows meshes and the wing meshes by clicking their visibility off in the Group list.

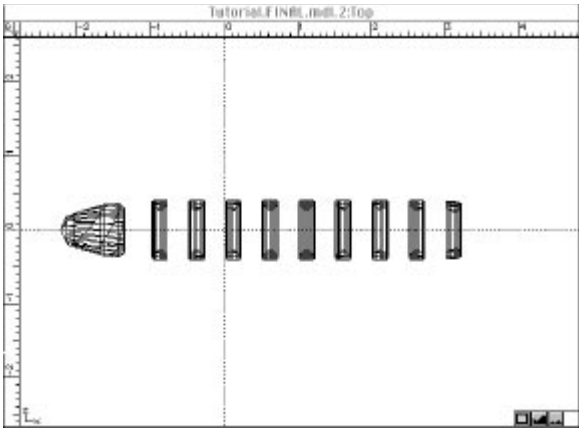


Using the Groups palette to turn “off” one set of fuselage.windows mesh.

Creating the Outer Surface of the Windows

For our first boolean, we will create the intersection of the outer fuselage and the set of the window cylinders and the cockpit extrusion. The effect will be that of taking the cylinders and the cockpit and grinding off all the material that lies outside the volume of the outer fuselage. Keep in mind that booleans can only have one target object (one object operated on), but many objects operating on the target. For this reason, we select the outer fuselage first. Select the fuselage object and then choose the Boolean tool. A red box should appear around the fuselage, signifying that this is the target object that the boolean will be performed on. Now hold the Shift key down and select the cockpit extrusion and all the window cylinders (order doesn't matter). Set the radio button in the Boolean tool bar at the top of the screen to "Intersection". Depending on how fast your machine is and how much RAM you have, type in a mesh density value in the 'Mesh Density" box. A value between 3 and 6 are recommended for the tutorial.

Set the mesh density according to the following criteria: How smooth you want the model to appear? How much horsepower is available to the software- processor, RAM, accelerator boards? How much time can you afford? Some booleans can take many minutes depending on your hardware and the complexity of the boolean. How "accurate" is the resulting boolean? Occasionally, in a complex boolean, errors in creating the can occur in the form of stray polygons. A way to correct these errors is to increase the mesh density, which will increase the calculation time. In general, start with a low mesh density and increase it to resolve the above issues.

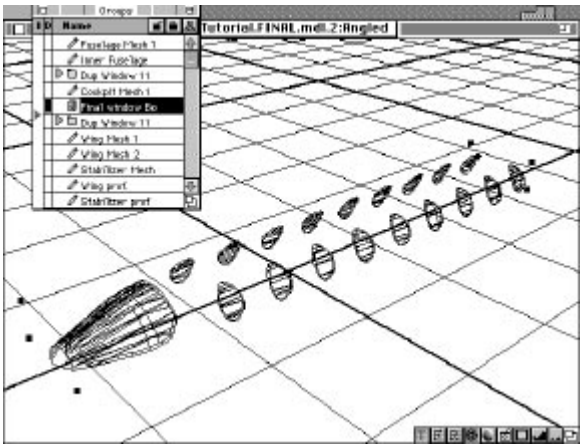


Result of Intersection boolean operation.

Hit the “Make It So” button and wait for the Macintosh to crunch out the boolean. Depending on your machine and mesh density, it might be a short wait. When completed, the model will look different, comprised of a swarm of triangles. This is because it is now a polygonal mesh. Note that you can no longer “touch” the vertices that make up the mesh, although Scale, Mirror and Rotate tools will still work.

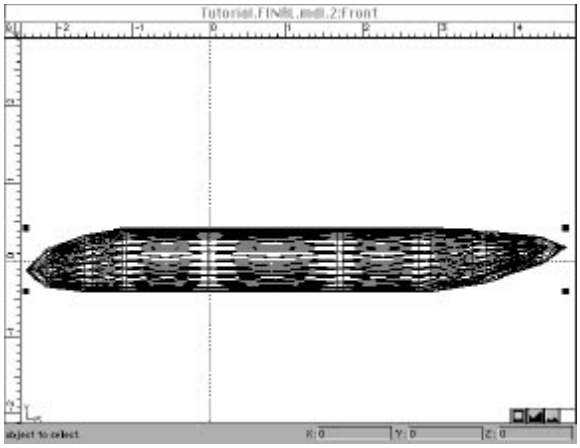
Creating the Inner Surface of the Windows

So now that you have the outer surface of your glass, the last step is to carve out the inner surface, forming the window panes. To do this, select the boolean you just created in the Group list, click on the Boolean tool and then click on the inner fuselage object. In the Boolean tool bar, click the “Difference” radio button and then hit the “Make It So” button. Leave the mesh density setting as the same for the first boolean. In moments, your windows are done.



Result of Difference boolean operation.

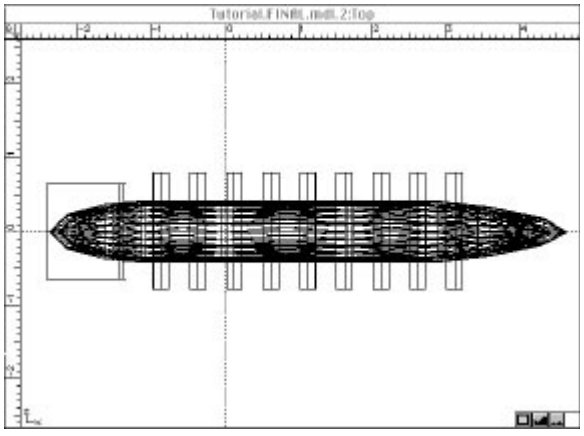
Creating the Inner and Outer Walls of the Fuselage



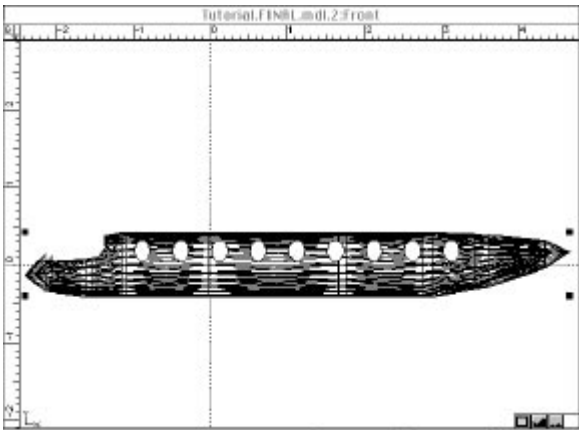
For now, turn off the window boolean. Now turn on the second set of fuselages, cockpit shape and window cylinders that you cloned in Step 13. To make a thick-walled fuselage, select the outer fuselage, choose the Boolean tool and then select the inner fuselage. Make sure the radio button in the Boolean toolbar is set to “Difference”, and the mesh density is the same as the density used to make the window boolean and hit the “Make It So” button. After a short wait, you should see a fuselage polygon mesh with an inner and outer wall, the difference between the outer and inner spline mesh.

Creating the Cockpit window

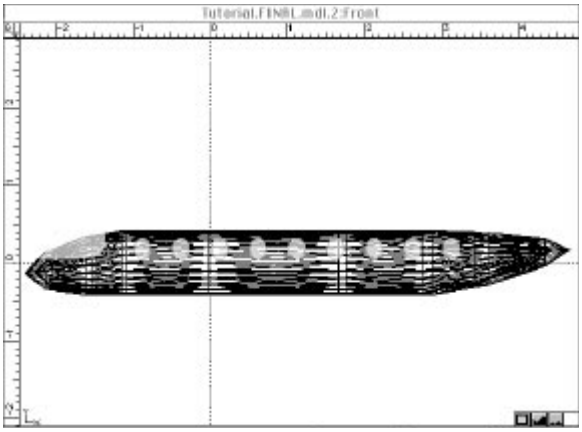
The final step for the design of the fuselage is to cut out the cockpit and window holes that match exactly to the window boolean you’ve created. Select the thick-walled fuselage boolean just created, select the Boolean tool, make sure the radio button is set to “Difference” and the mesh density is the same as in previous steps and then shift-select the cockpit extrusion and the window cylinders. Hit the “Make It So” button. When you turn on the window boolean, you should get a perfect match of fuselage to windows.



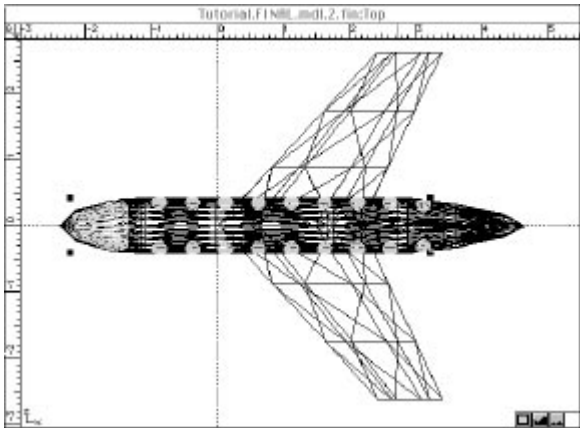
The cockpit and windows cylinders



Cut the cockpit and windows



Fuselage and windows visible

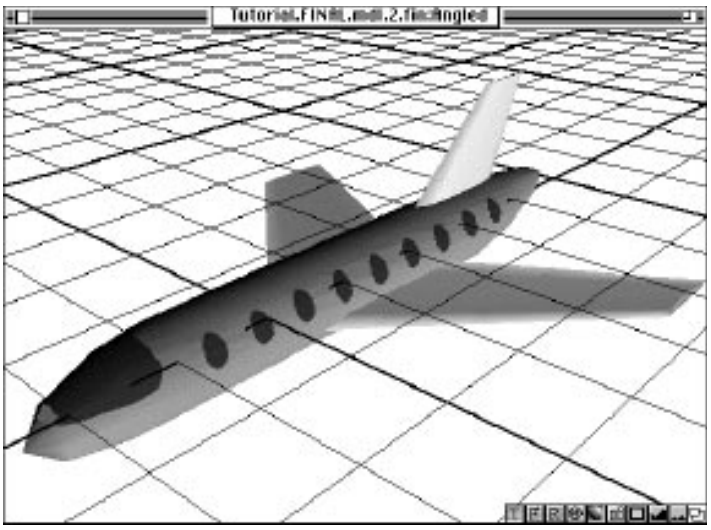


All part visible

Welding the Components

The finishing touch is to “weld” all the fuselage and wing pieces together into a single element.

If you plan to texture-map/color the wings separately from the fuselage in PresenterPro, skip this step since once the pieces are welded, they cannot be separately treated.



Shaded preview

To weld, choose the Boolean tool first, then select the fuselage, then turn on the two wings and the stabilizer. Click the “Union” radio button, select the wings and stabilizer and hit “Make It So”. Now the only active pieces should be the windows boolean and the complete fuselage boolean.

Now go to the Angled Window view and select the Shaded Preview
icon at the bottom of the window. View the fruits of your labor. Have you noticed that this is somewhat quicker than modeling with traditional Lathe/Extrude/Reshape tools? Good work! Your model is ready for rendering.